RESEARCH ON APPLICATIONS OF MINI-TURBOJET AND TURBOJET ENGINED MILITARY UAVS

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Abstract: *This study examines the diversity of unmanned aerial vehicles (UAVs) in recent years and the developments in these areas. The use of these aircraft in different areas, especially in military areas, has evolved rapidly. Due to this development, additional requirements emerged. At this point, the increase in these properties increased the weights of the UAVs and led to the search of high-thrusting engines. The aim of this study is to investigate the integration of mini-turbojet and turbojet engines from the class of gas turbines with high propulsion power into the UAV systems. Within the scope of our aim, the working principles of gas turbines, their types and turbines which on development stages are briefly introduced. The types of engines used in UAVs are tried to be explained with some vehicles. Examples of mini-turbojet air vehicles used in the past are given and current works of private companies are mentioned. As a result of the researches, it was concluded that there was no examples of fleet level of UAVs with turbojet engines and the development studies are continued today.*

Keywords: *Gas Turbines, Mini-Turbojets, Turbojet, Unmanned Aerial Vehicle (UAV)*

1. INTRODUCTION

In recent years, popularity on UAV has become very prominent, and it will continue to increase of popularity on UAVs [1]. If it should support this argument, in Europe, number of UAV was 181 in 2012, this number increased to 1032 in 2016 [2]. Especially UAV is used for military and civil application domains extensively. Also in civil markets for people who are professions and curious mini UAVs became easy to reach. Users used in different domains related to this easy accessibility. Users began using them for their scientific data and some exploration business [3]. Some examples of this saving rare creatures in places that has less accessibility. In addition to these examples they were used in some actions as illegal hunting, destruction of forests. While new areas are added in the civilian and military domains new capabilities are expected from the UAVs due to the increase of in these technologies. Some of these capabilities can be listed as follows; day and night high-resolution imaging, early warning system, low noise level, precision guided munitions, tactical strike and defense system, effective maneuverability and low visibility on radar are some of them. As integration of these capabilities that was added to UAVs was useful increases of the weight. Depending on its weight, it needs propulsion power which ought to be enough to fly toward the weight. With the increase in automation and digitization developments in aviation area [4], the work of unmanned aerial vehicles has gained more importance.

In addition to these examples increasing number of UAVs on military domains caused and accelerated on the new generation of high speed fighter UAVs that could destroy these unmanned aerial vehicles. In these researches a problem occurs in high speed propulsion power that was a similar problem in 1950's as ramjets and turbojets engined UAVs. That researches described as ancestor of UAVs at this point, this article inspects from 1950's to recent examples of models of turbojet engined UAVs and development of turbojet engined UAVs.

2. GAS TURBINES

Gas turbine engines are engines designed to convert the chemical energy that is generated by the combustion of the fuel, into another useful power, such as shaft power or high-speed thrust [5, 6].

Mini-turbojet and turbojet engines are gas turbine engines used for propulsion in UAVs. In generally gas turbine is located in the vehicles tail section and there are many important tasks [7]. These engines are particularly suitable in target and reconnaissance platforms, especially in military domains [8, 9]. There is no difference between in the working principles of mini-turbojet and turbojet engines [10].

3. TURBOJET ENGINES USED IN UAVS

The most common types of air craft engines used in aviation are gas turbine engines and piston engines. The piston engine types are simple-designed, fuel-efficient motors and are often used in small aircraft. In general, these engines lose their performances at high altitudes and if piston engine gets boosted its weight becomes heavier as engine size. Increasing the weight is a problem in aircraft design. Gas turbine engines are the engines that can fly at every altitude and produce high-speed, torque and bleed air [11, 12].

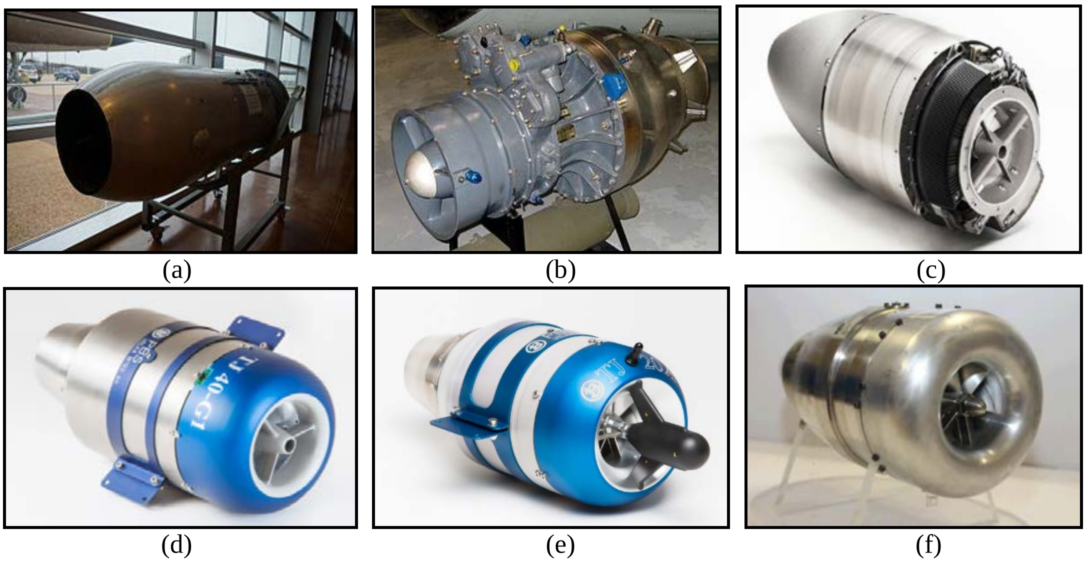

FIG. 1. Turbojet engines used in UAVs, (a) Fairchild J44 Small Turbojet Engine [13], (b) Teledyne CAE J69 Small Turbojet Engine [14], (c) PBS Aerospace TJ100 Turbojet [15], (d) PBS Aerospace TJ40 Mini-Turbojet [15], (e) PBS Aerospace TJ40 Micro-Turbojet [15], (f) TEI TJ90 Turbojet Engine [16]

Characteristic factors of the motors used in unmanned aerial vehicles differ on size, fields of use, etc. The engine used for a UAV for the purpose of reconnaissance may not provide the required efficiency when it is integrated into the UAV that will be used in another field.

As in aviation applications, the increase in the size of the aircraft due to the increase in aircraft size also applies to UAVs.

The turbojet engine was developed in 1940 by the Fairchild engine division. In 1944, Fairchild J44 (see Fig. 1.a) was used in target aircraft, missiles and as jet support into some aircraft [17].

Teledyne CAE J69 (see Fig. 1.b), an example of a small turbojet engine, was developed under the license of CAE Continental Aviation and Engineering. In the US, some airplanes were used as propulsion power to missiles and small UAVs. The Teledyne CAE J69 was developed to work at higher altitudes, and the J100, the top model, is out [18, 19, 20].

PBS Aerospace TJ100 (see Fig. 1.c) is a 4th generation turbojet engine and especially suitable for unmanned aerial vehicles. They can be used in military domains such as rescue and reconnaissance and also in other tasks for military domains. These engines are also ideal for glider experimental aircraft. The TJ 100 engine has a compact design and has low fuel consumption and excellent power rating for the output category. This engine is also suitable for landing into the water [15].

PBS Aerospace TJ40 Mini-Turbojet (see Fig. 1.d), has been developed to confuse enemy air defense systems and small reconnaissance aircraft. It is a turbojet engine used in UAV systems such as target aircraft and feed aircraft. It has a weight of only 3.25 kg, a thrust of 395 N and an advantage of 98,000 rpm max [15].

PBS Aerospace TJ40 Micro-Turbojet (see Fig. 1.e), is a turbojet engine designed for UAV systems, such as target drones and decoy drones, in order to confuse enemy air defenses and small reconnaissance drones. TJ40 mini-turbojet is used in UAVs systems such as target aircraft and feed aircraft. It only has a 1.98 kg weight and 210 N thrust power and a max revolution of 115000 rpm. It has a fuel pump and an electric spark plug located in the casing of the combustion chamber. Ideal for UAV systems [15].

In 2011, TEI TJ90 Turbojet Engine (see Fig. 1.f), has been started to provide a higher thrust than TJ35 turbojet engine development work in TEI plant in Turkey [16].

4. TURBOJET ENGINE APPLICATIONS IN MILITARY UAVS

Military aircraft are required to fly in all environmental conditions worldwide. They have to achieve success in the various and critical maneuvers they use in their operations [21]. Mini-turbojet and turbojet engines are gas turbine engines used to thrust unmanned aerial vehicles.

Radioplane Q-1 (see Fig. 2.a) was born from the need of a high-speed target aircraft of the US air force in 1950 and was manufactured as an advanced turbojet-powered aircraft. Radioplane Q-1 was launched by carrier planes and without the landing gear, landing operation carried out by the help of parachutes. The Continental YJ-69 turbojet engine was used in The Radioplane Q-1, the air required for the jet engine supplies from the space in its nose. Newly developed Ryan Q-2 aircraft ended its production. Radioplane Q-1 played a pioneer role in the development of air defense missiles [28, 29].

The Ryan Firebee (see Fig. 2.b) was developed in 1951 and is the most widely used target aircraft ever. The Ryan Firebee plane was launched with the aid of a carrier or with the aid of the rocket-assisted take-off RATO on the launch pad. Fairchild J44-R and Continental J69-T turbojet engines were used in Ryan Firebee [30]. In the developed models, various control systems have been installed to provide fighter maneuverability. They are also equipped with wingtip thermal flares, which aims to target wing fins rather than engine exhaust that will protect them from heat-oriented missiles. Developed radar devices that allow imitating aircraft [31].

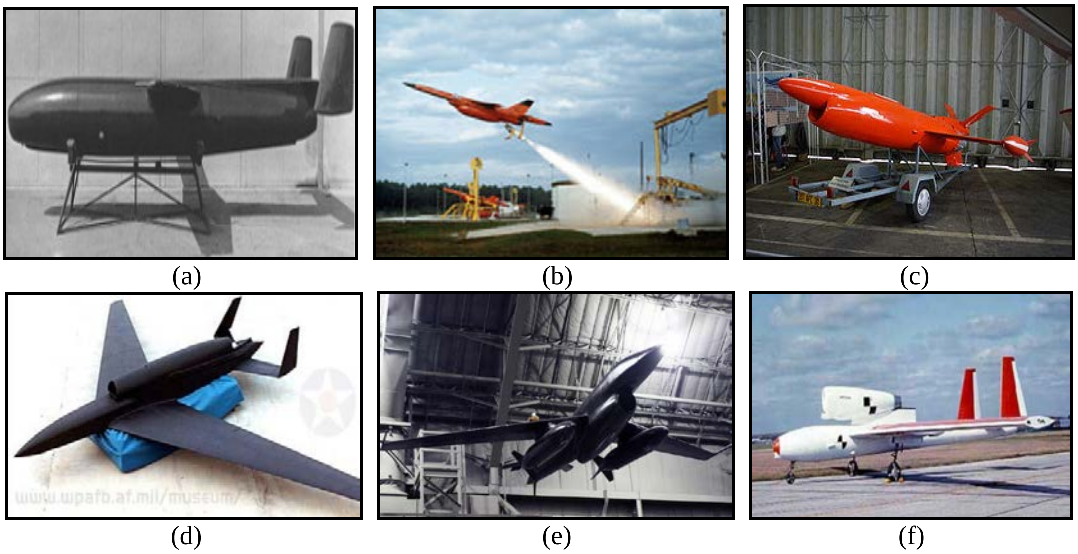

FIG. 2. Turbojet engine applications in UAVs , (a) Radioplane Q-1 [22], (b) Ryan Firebee [23], (c) Nord Aviation CT20 [24], (d) Teledyne Ryan AQM-91 Firefly [25], (e) Ryan Model 147 Lightning Bug [26], (f) Boeing YQM 94A Compass Cope [27]

Nord Aviation CT.20 (see Fig. 2.c) was evolved in 1957 by developing from the SFECMAST5.510, a remote controlled target aircraft with a French turbojet engine. After the start of the turbojet, the target aircraft is placed on a ramp and launched using two rockets. During the flight, the aircraft is controlled by radio signals from the ground. Because of its lightweight material, it can float and be recovered if it is forced into water [32].

In 1966, Teledyne Ryan Firefly (see Fig. 2.d) developed on the basis of long-range high-altitude, photographic exploration and made its first flight in 1968. Teledyne Ryan AQM-91 Firefly is a subsonic UAV operating with General Electric J97 turbojet engine. It can climb to a height of 23700 m after launching from the carrier aircraft. Since there is no landing gear, it’s landing operation carried out by parachute. A microwave command routing system has been used and stage of the flight was controlled by the Doppler/Inertial navigation system, which had a precision of about 0.5% of the distance. The primary task equipment is the Itek KA-80A panoramic camera. It is also equipped with IR (instrument flight authorization) sensors and ELINT (electronic intelligence equipment).

Teledyne Ryan Firefly is specifically designed for low observability, it has a sharped nose, a round fuselage, and an inwardly folded tail. The engine mounted on the top of the fuselage and the signature of the IR are minimized. Non-metallic structural elements and critical fields were made of radar absorbent material to further reduce radar reflection. Teledyne Ryan Firefly has been removed due to changes in the requirements of conditions [33, 34, 35].

The Ryan Model 147 Lightning Bug (see Fig. 2.e) series is produced as a target aircraft operating with the Teledyne J69 turbojet engine. Ryan Model 147s are manufactured without landing gear to save weight and they are able to perform in the aid of their parachute. Served in different positions in the US Army from 1962 to 1975, each of the UAVs became stronger, and more equipped than previous model. The tasks of the Ryan Model 147 series include high and low altitude photography, electronic antenna discoveries, reconnaissance, electronic warfare, pointing memory and psychological warfare. In addition, a simple warning system called AN/APR-26 is integrated into the Ryan Model 147E.

The next model, Ryan Model 147 F, also carries the system AN/ALQ-51, which manipulates radar signals, confusing that the target is in another position from the actual position. They are painted in black with high visibility at low altitude. Another feature of these unmanned aircraft is that they are radio controlled by the crew on the carrier aircraft instead of using an automatic guidance system. It has an advanced camera system and can display a 96-kilometer landmark. The forward model of this series, Ryan Model 147SRE, uses an almost unrecognizable infrared flash and infrared film from the ground that provides night exploration. BGM-34 model has precision-guided ammunition to carry out various ground strikes and defense missions on these aircraft. It is also powered by the Teledyne CAE J69-T-41A (8.5 kN thrust) engine. This model has not been used in any task. A pre-programmable digital flight control system was added to increase the maneuverability of the Model 147 series and test flights up to 10G were performed.

Although they were produced for exploration and espionage in 1972, they were replaced by F-4 Phantom planes and used leaflet bombs. Furthermore, the top models of the Ryan Model 147 Lightning Bug were fitted the Teledyne J100 turbine engines. In the aid of these engines, they would perform at 23000 m and 1260 kg thrust power. Because of all of these features, Ryan Model 147 Lightning Bug will be the ancestor of the new generation jet UAVs that will be produced in the future [34, 36].

The Boeing YQM 94A Compass Cope (see Fig. 2.f) was created in the military and intelligence department for higher-performance, high-altitude long-life UAV requirements. In addition to these requirements, it was necessary to take a traditional air runway alone and takes up to 24 hours of service. Moreover, it should be able to perform operational tasks under the conditions of day and night and in all weather conditions, and should also be able to obtain battlefield exploration, signal intelligence, photographic exploration, ocean reconnaissance and atmospheric sampling [37].

CONCLUSIONS

In recent years, with the increase of varieties in unmanned aerial vehicles a transaction from the reconnaissance to air defense and attack function has been observed. This function change resulted some problem, such as useful load, high altitude and speed have initiated the search for new propulsion power. Although turbojet engines are the power, turbojet engines have still no permanent solution for high sound and high fuel combustion. These two limiting factors reduce the efficiency expected from the UAVs. In addition to this, due to the fact that UAVs are independent of human physiology, it is thought that they will replace manned warplanes later on. Therefore, this and other similar studies are very important. At present, it is deduced that there is no examples of UAVs which possess turbojet engine yet at the level of fleet, and it is a continuing process of searching and developing.

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